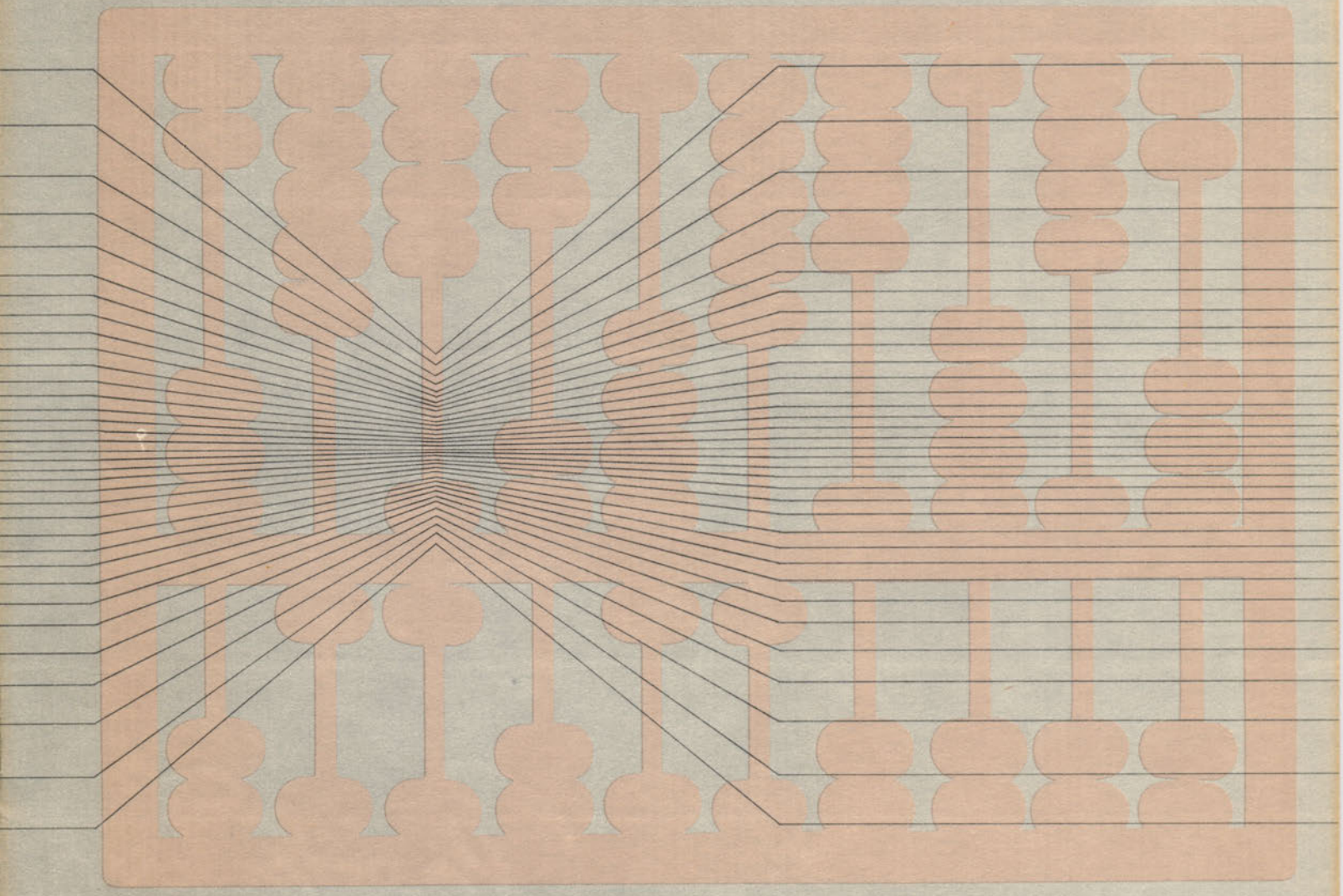
I. P. Sharp Associates

SHARP APL
Plot Facility



SHARP APL PLOT FACILITY

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The SHARP APL Plot Facility is proprietary software developed by I. P. Sharp Associates. This manual has been prepared to assist SHARP APL users in the application of the Plot Facility.

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CONTENTS

	PAGE
Introduction	1
Default Use	2
The State and How to Change Options	4
Plot Type - I. Plotting Using the APL Typesphere	5
- II. High-resolution Plotting	7
Specifying Scale Limits	9
Selecting the Abscissa	10
Axis Controls	11
Specifying the Plot Characters	12
Varying Plot Symbols Within a Data Column	13
Display Size and Decoration Pattern	15
Scale Formats and Annotation	17
Using Logarithmic Scaling	20
Interchanging the Axes	22
Omitting or Doubling One or Both Axes	23
Output Options	24
Using Files for Input and Output	26
Support for Various Types of Terminals	27
Appendix A: Summary of State-Setting Functions	28
Appendix B: Summary of Error Reports	33
Appendix C: Application Package Considerations	37
Appendix D: Some Examples of Use	38

Introduction

The SHARP APL Plot Facility is a flexible set of programs which produce data in graphic form on a typewriter terminal. Using the Plot Facility makes it possible to obtain a quick and easily understood picture of the data. A wide range of options permits automatic operation while maintaining user control over the exact format of the display. Further, the quality of the display is suitable for publication with less cost and more accuracy than hand-drafting techniques.

Among the features available are:

* support for most APL-compatible terminals
* input and output file options
* automatic or selectable scale limits
* complete control over size of results
* histograms
* high-resolution plotting (900 points per square inch)
* output compatible with SHARP APL text editors
* logarithmic scaling options
* choice of plot symbols
* transposition of axes
* omission or doubling of axes
* multiple variables
* title and scale annotation

Workspace 3 *PLOT* contains the main function (also called *PLOT*) and associated state-setting functions, which control the various options available. They will operate in origin 0 or 1, and they are independent of the digits setting.

Default Use

The default settings are those that are in effect when you load the plotting workspace, 3 *PLOT*. For information on how to alter these settings, see the section entitled "The State and How to Change Options".

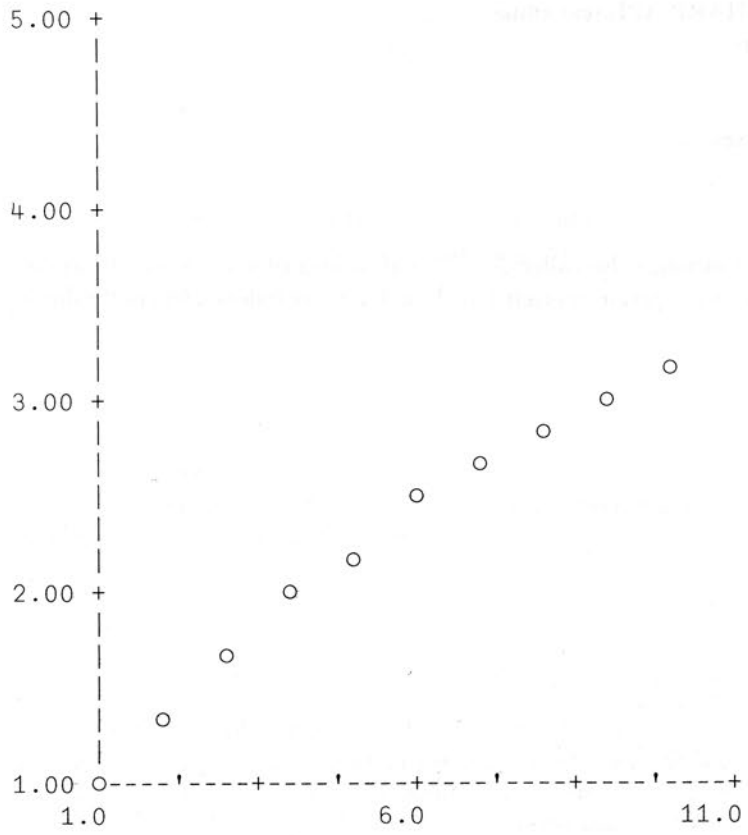
The default syntax of *PLOT* is:

PLOT **data**

where **data** is a vector or matrix of numbers. Non-numeric or incorrectly formed arguments will result in an appropriate error report.

A vector argument is plotted using the integers 1,2,...,⍴*DATA* as the abscissa.

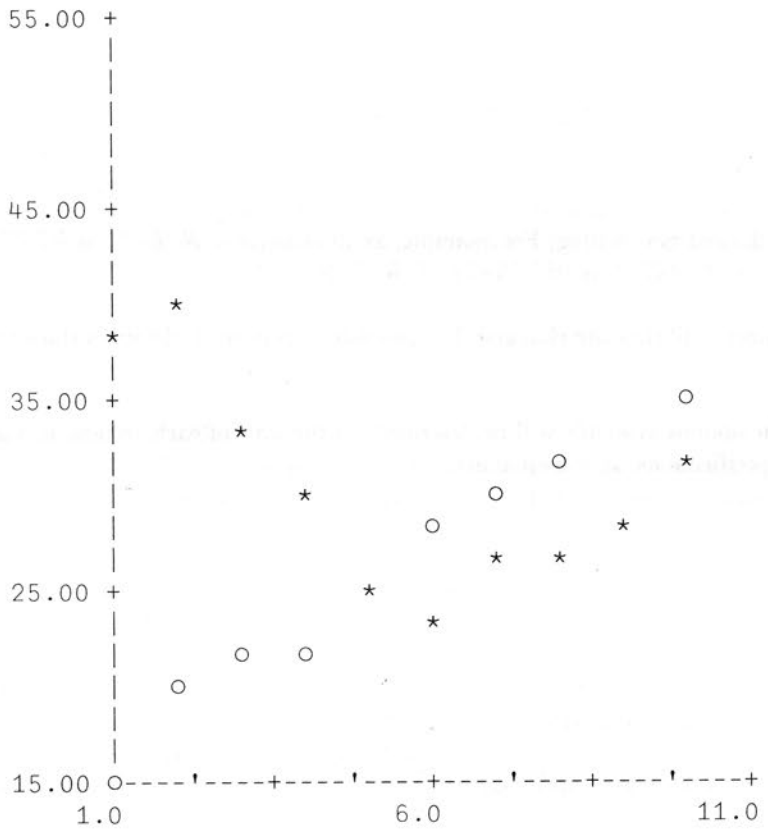
```
PLOT (⍳10)*0.5
```



The ordinate scale values are automatically selected so that the points approximately "fill" the default plot size (24 vertical lines by 40 horizontal spaces), incrementing by whole numbers if possible.

When the argument is a matrix, the first column is plotted using the symbol o and the second column using the symbol *.

```
     DATA
 15  39
 20  40
 21  34
 22  30
 25  25
 29  23
 30  26
 31  27
 29  29
 35  31
     PLOT DATA
```



The ordinate scale values are selected to include the lowest value (15) and the highest (40) with preference being given to selecting non-fractional increments. With the default options on effect, where two or more points coincide the symbol associated with the latter column is used.

The State and How to Change Options

The function *STATE* will display the current options that have been chosen, or the default values for specifications which have not been altered. The example here shows the output of *STATE* when all default values are in effect.

```
      STATE
APL ◇ PRINT ◇ NORESULT
NORMAL ◇ SINGLE ◇ UPRIGHT
SRCFILE 0 ◇ OUTFILE 0
ABSCISSACOL 0 ◇ SYMBOLCOL 0
AXES FIXED
ALL LIMITS AUTOMATIC
SET ORDINATE TOTAL  5  SPACED  6  NUMBERED  1
SET ABSCISSA TOTAL  5  SPACED 10  NUMBERED  2
ORDINATE AXIS SINGLE ◇ ABSCISSA AXIS SINGLE
ORDINATE SCALE LINEAR ◇ ABSCISSA SCALE LINEAR
ORDINATE FORMAT 'F10.2'
ABSCISSA FORMAT 'F10.1'
TITLE TEXT BLANK
ORDINATE TEXT BLANK
ABSCISSA TEXT BLANK
PLOTCHARS 'O*X+∘∇Δ⍞⊤⊥⍵⊂⊃∩∪'
```

To change an option, just enter the desired new setting. For example, an alternative to *NORMAL* is *HISTOGRAM*, and an alternative to *ALL LIMITS AUTOMATIC* is *ORDINATE LOW LIMIT* 0.

The options that are set remain in effect until they are changed. It is possible to restore all default values by typing *DEFAULT*.

In the sections that follow, each of the options available will be described. At the start of each section, it is assumed that all options carry their default specifications, as shown above.

Plot Type

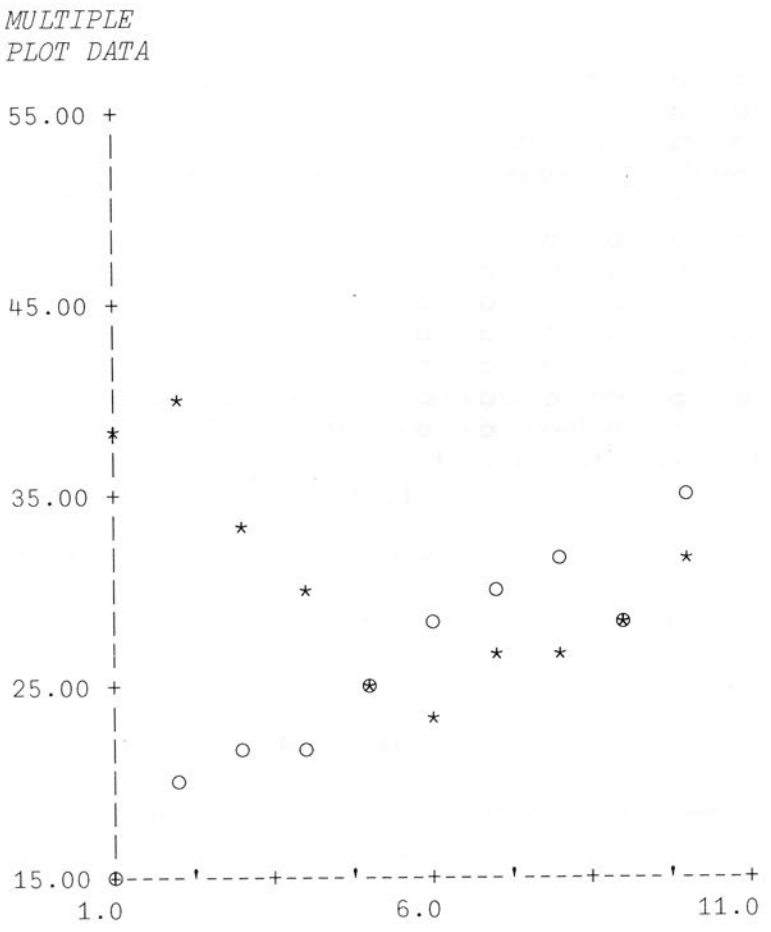
Four major types of plots are available. Two of them use the APL typesphere as the print element; these are discussed in Part I below. The remaining varieties offer support for high-resolution plots, and are dealt with in the latter part of this section.

I. Plotting Using the APL Typesphere

The standard APL typesphere gives a resolution of 6 (vertical) by 10 (horizontal) points per square inch on a 10-pitch terminal.

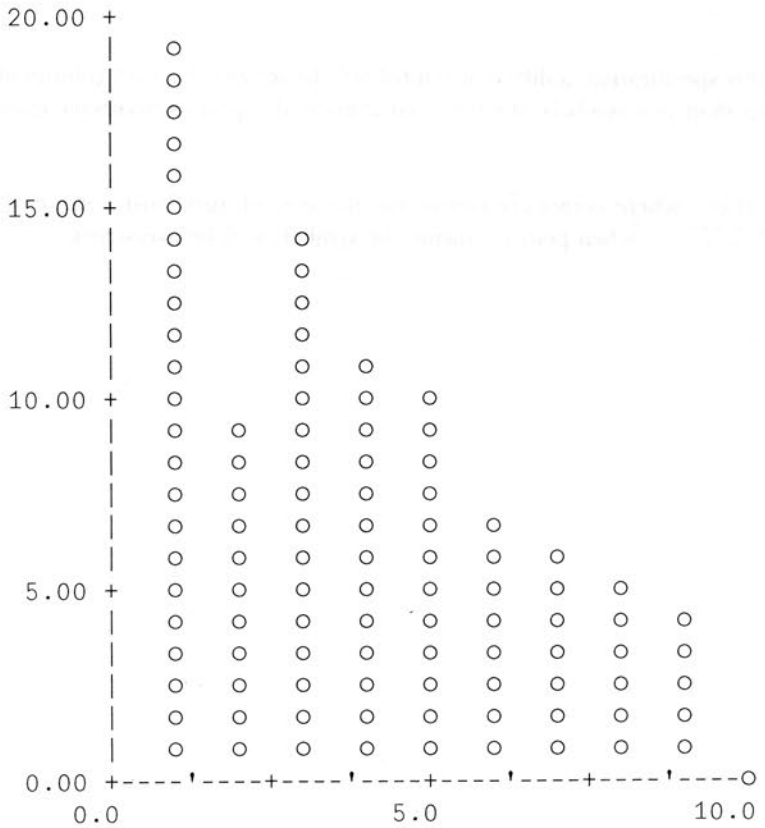
The default plot type is *NORMAL*. With this specification, a different symbol will be selected for each column of the argument. If there are more data columns than plot symbols, the plot characters will repeat as necessary from the beginning of the sequence.

With the default setting of *SINGLE* in effect, where points are concurrent the symbol associated with the latter column will be used. With the option *MULTIPLE*, when points coincide the symbols will be overstruck.



The option *HISTOGRAM* produces a histogram of the data. Once a data point is plotted, it is reprinted in the same horizontal position on each subsequent line in the graph. Either *SINGLE* or *MULTIPLE* may be specified with this option, as appropriate. If *MULTIPLE* is used, points will be overstruck from the concurrent point downward in the output column.

```
HISTOGRAM
ABSCISSA LOW LIMIT 0
PLOT 19 9 14 11 10 7 6 5 4 0
```



II. High-Resolution Plotting

High-resolution plotting requires a plotting typesphere (IBM part number 1167114, available through I.P. Sharp Associates). This typesphere uses a special set of symbols to give a resolution of 30 (vertical) by 30 (horizontal) points per square inch on a 10-pitch terminal printer.

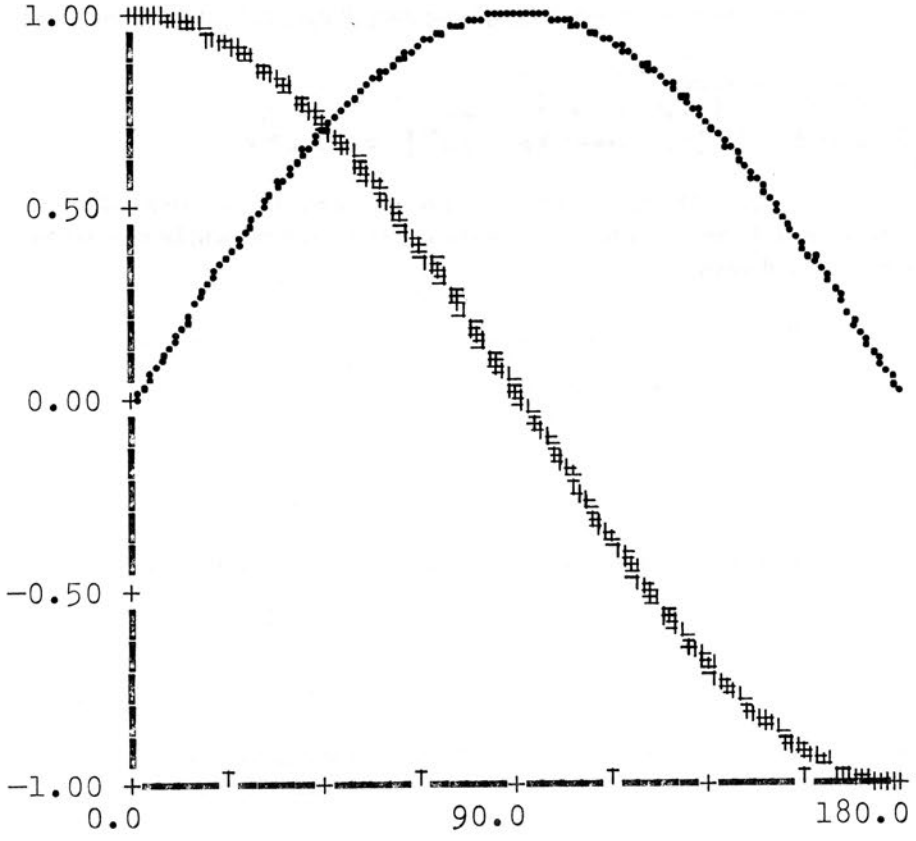
The APL typeball contains many characters that are not available on the plotting typesphere. Following is a list of APL symbols that can be used in title or scale annotation, as well as qualifier text in format phrases, with the high-resolution plotting options. Below each symbol is the corresponding translated character that will result when using the plotting typesphere.

APL Typesphere	*A* to *Z*	0 to 9	[] ( ) . ,	+ - ¯ × ÷ ⋆	$ ⍵ ~ | / =	→ ↑ ↓ ←
Plotting Typesphere	A to Z	0 to 9	( ) ( ) . ,	+ — t % ⋆	$ ⍵ ⌜ ▌ / =	› ↑ ↓ ‹

Two high-resolution plotting options are available. The first, *FINEPLOT*, provides three distinct symbol-sets: the dot, the cross, and the overstruck dot-and-cross. If the matrix has more columns, the forth column will be represented by the same symbols used for column one, and so on.

Here is an example of using *FINEPLOT* to plot sines and cosines.

```
FINEPLOT
ABSCISSA LOW LIMIT 0
ABSCISSA HIGH LIMIT 180
PLOT ⍉ 1 2 ∘.○(0,⍳180)×○÷180
```



The second high-resolution plotting option is *FINEAPL*. *FINEAPL* is like *FINEPLOT*, except that it permits the user to plot certain APL-like symbols on a high-resolution plot, thus increasing the number of distinct symbol-sets that can be plotted to six. The symbol-sets available with *FINEAPL* are the three used by *FINEPLOT*, followed by the sequence ○ ⋆ ⊛. If the argument to *PLOT* has more than six columns, symbol-sets will repeat as necessary. *FINEAPL* and *FINEPLOT* will produce identical results if the number of columns to be plotted is three or less.

Note that the *SINGLE* versus *MULTIPLE* specification is ignored when using either high-resolution plotting option.

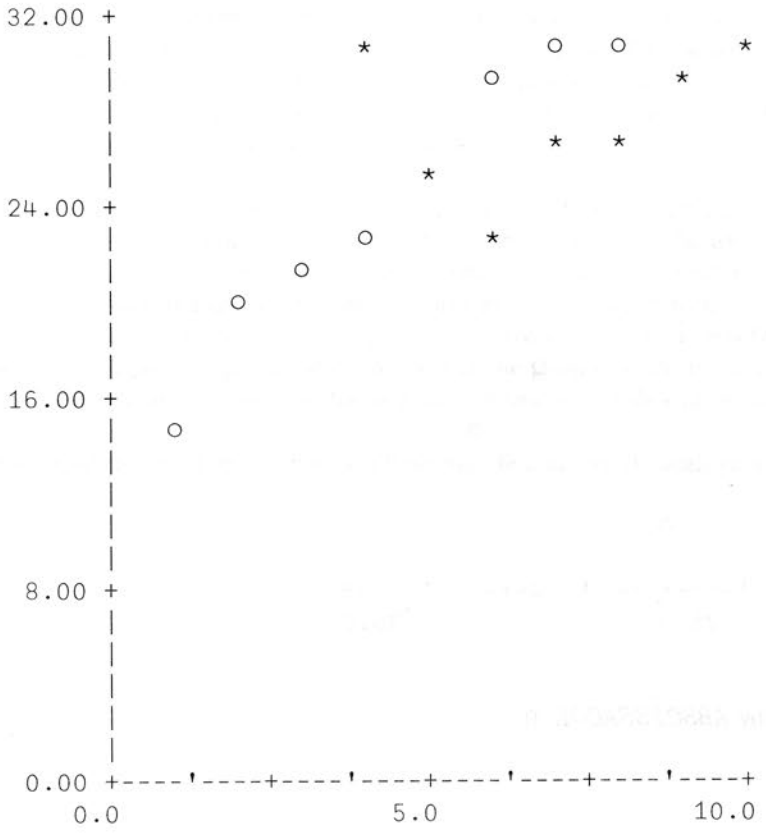
Specifying Scale Limits

Complete control is provided over the scale limits associated with each axis on the plot. The default setting is *ALL LIMITS AUTOMATIC*. For more precise control, any of the following may be specified:

ORDINATE	*HIGH*		*AUTOMATIC*
or	or	*LIMIT*	or
ABSCISSA	*LOW*		numeric value

The following example uses the matrix *DATA* on page 3.

```
ORDINATE LOW LIMIT 0
ORDINATE HIGH LIMIT 32
ABSCISSA LOW LIMIT 0
PLOT DATA
```

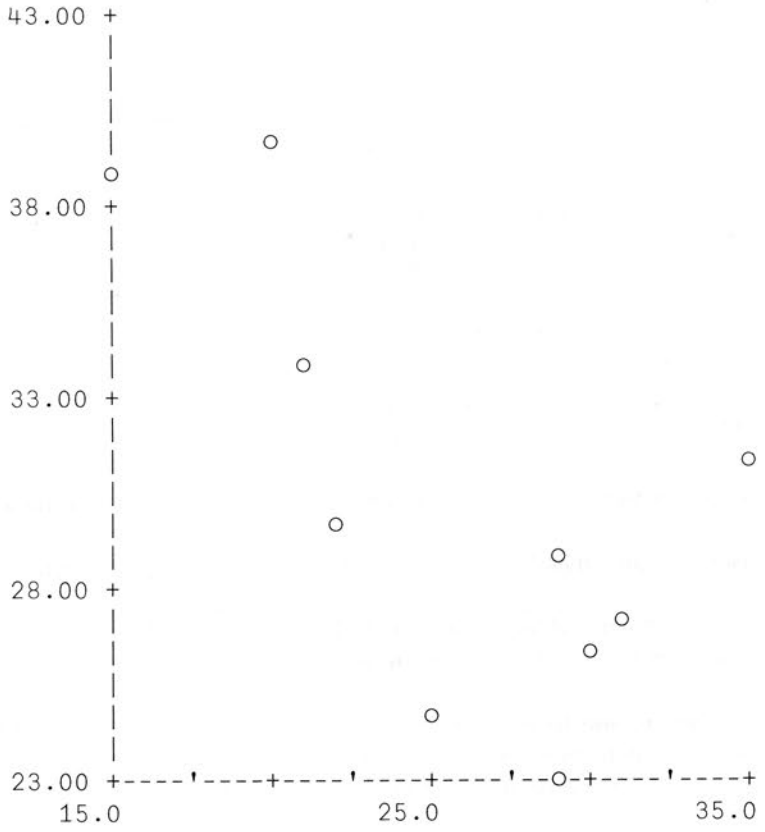


Note that any values which lie outside the specified limits are not plotted.

Selecting the Abscissa

In the default case, each number in a column of the argument is plotted against the position of that value within the data column. You may designate one of the columns to be used as the abscissa values by selecting the option *ABSCISSACOL* **n**, where **n** is one of the columns of the argument. All other columns then become the ordinate on the graph and are plotted as the dependent variables.

```
ABSCISSACOL 1
PLOT DATA
```



The default condition can be restored by *ABSCISSACOL* 0.

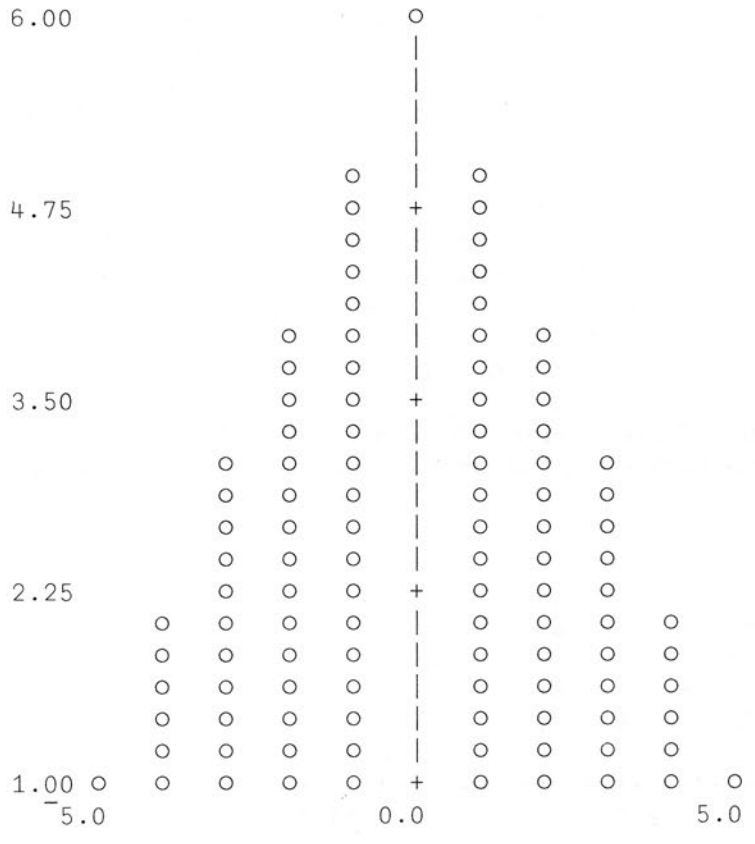
Axis Controls

With the default setting *AXES FIXED*, a border is drawn at the left and bottom edge of the graph. With the option *AXES FLOATING*, a horizontal line and a vertical line are drawn through zero, wherever it may appear on the plot. If zero is not marked on the scale of an axis, then no line is drawn for the **other** axis. For example, if zero does not appear in the numbers associated with the ordinate scale, then no abscissa is drawn (as illustrated below).

When using either *FINEPLOT* or *FINEAPL*, the border or zero-line will be a broad stroke with the default *AXES BROAD*, or a fine stroke with the option *AXES FINE*. This option does not apply (is ignored) when not using one of the two high-resolution plotting options.

The axis control options may be specified conveniently on one line, for example, *AXES FIXED, FINE* .

```
HISTOGRAM
ABSCISSACOL 1
AXES FLOATING
ORDINATE LOW LIMIT 1
ORDINATE HIGH LIMIT 6
PLOT (¯6+⍳11),[1.5] (⍳5),⌽⍳6
```



Note that no abscissa axis is drawn, since zero is not marked on the ordinate scale.

Specifying the Plot Characters

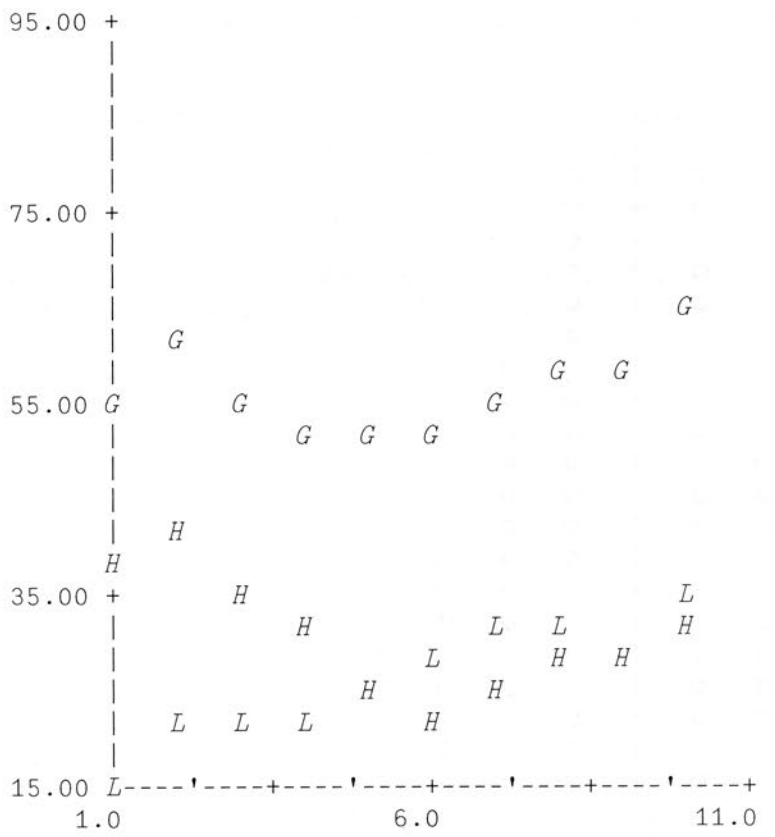
The default sequence of characters plotted, corresponding to the columns of the argument, is ○ ⋆ × + ∘ ∇ ∆ ⍞ ⊤ ⊥ ⍵ ⊂ ⊃ ∩ ∪ . You may change this sequence by entering *PLOTCHARS* '⍞∘×', or any set of characters. In certain applications it may be useful to use digits or letters as the plot characters.

If the *ABSCISSACOL* option is being used, then the column used for the abscissa is ignored for the purpose of associating plot characters. Hence the plot characters used will correspond to the successive data columns in the argument matrix.

If there are more columns to be plotted than plot characters, the symbols will be repeated as necessary, starting from the first symbol in the plot character sequence. This can be used to produce useful effects, particularly when combined with the *SYMBOLCOL* feature to be discussed in the next section.

Specified or default plot characters are ignored when using *FINEPLOT* or *FINEAPL*, since the typesphere required for those options has its own special set of characters.

```
PLOTCHARS 'LHG'
PLOT DATA,+/DATA
```



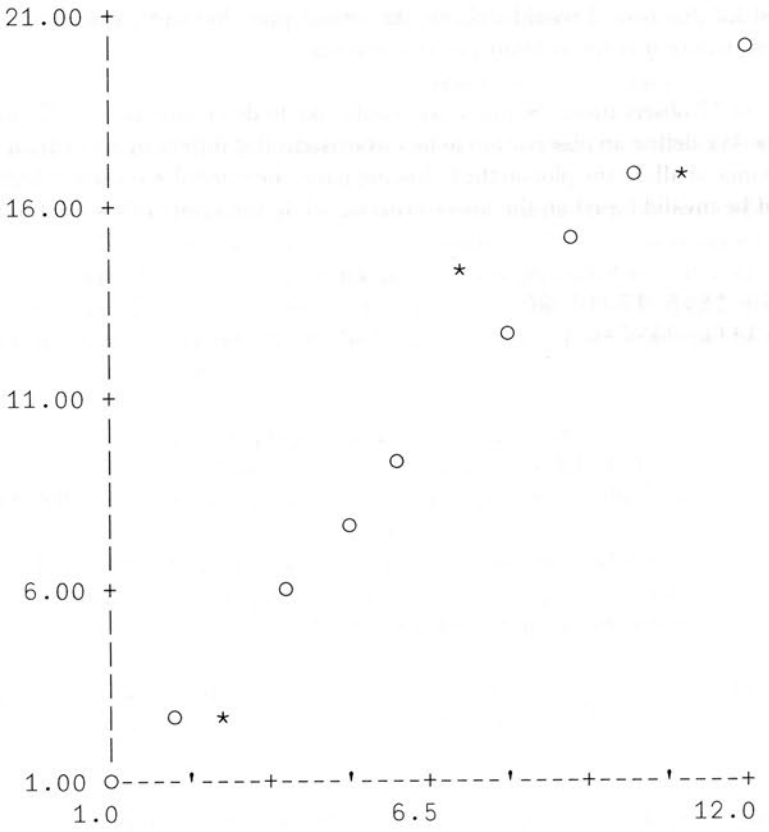
Varying Plot Symbols Within a Data Column

The symbol-column feature lets the user specify which plot character is to be used for a given point. For example, you may wish to highlight certain points by using a different character. To do this, construct one column of the data matrix consisting of positive integers designating the desired plot character for each point. The integer 1 would mean that the first plot character is to be used for this row, 2 would indicate the second plot character, and so on. Then simply select the option *SYMBOLCOL* **n**, where **n** is the column just constructed.

In the example which follows, *X* is a set of 12 observations. Suppose we would like to determine potentially invalid observations from these 12 pieces of data. We define an observation to be inconsistent if it differs by more than three from the previous one, or if it does not change at all. In the plot on the following page, the symbol * is used to highlight those points in *X* that we consider could be invalid based on the above criteria, while the symbol ○ is used to mark all other points.

```
   X← 1 3 3 6 7.5 9 14 13 15.5 17 17 20
   D←X-¯1⌽X ◇ X←X,[1.5] 1+(D>3)∨D=0
   X
 1       1
 3       1
 3       2
 6       1
 7.5     1
 9       1
14       2
13       1
15.5     1
17       1
17       2
20       1
```

```
SYMBOLCOL 2
ABSCISSA LOW LIMIT 1
ABSCISSA HIGH LIMIT 12
PLOT X
```



If there is more than one column to be plotted, the characters associated with each column are selected from the corresponding relative position in the plot character sequence. For example, suppose we had a five-column data matrix in which the first column was specified as the abscissa and the second as the symbol column. If, in a certain row of the matrix, the symbol designation were 2, then the three data points in that row would be plotted using the symbols corresponding to positions 2, 3, and 4 in the plot character sequence.

Display Size and Decoration Pattern

The default plot size (less annotation and scale markings) is four inches square, and the default specifications are:

```
SET ORDINATE TOTAL 5 SPACED  6 NUMBERED 1
SET ABSCISSA TOTAL 5 SPACED 10 NUMBERED 2
```

The meaning of each of these parameters is as follows:

TOTAL **t** is the total number of tics, or plus signs, that appear on an axis.

SPACED **s** is the number of lines (for the ordinate) or spaces (for the abscissa) between tics.

NUMBERED **n** defines which tics are to be numbered. Every **n**'th one will be numbered. Thus, each tic may be numbered by using *NUMBERED* 1. Alternately, the entire abscissa or ordinate can be unnumbered by specifying *NUMBERED* 0.

If desired, you may conveniently alter only parts of the specification for an axis. For example, *SET ORDINATE SPACED* 5 affects only the *SPACED* option and leaves the rest of the ordinate size and pattern as it was.

The size of the plot (in inches) may be determined by the following calculations:

vertical, 6 lines per inch	(**t**-1)×**s**÷6
vertical, 8 lines per inch	(**t**-1)×**s**÷8
horizontal, 10 pitch	(**t**-1)×**s**÷10
horizontal, 12 pitch	(**t**-1)×**s**÷12

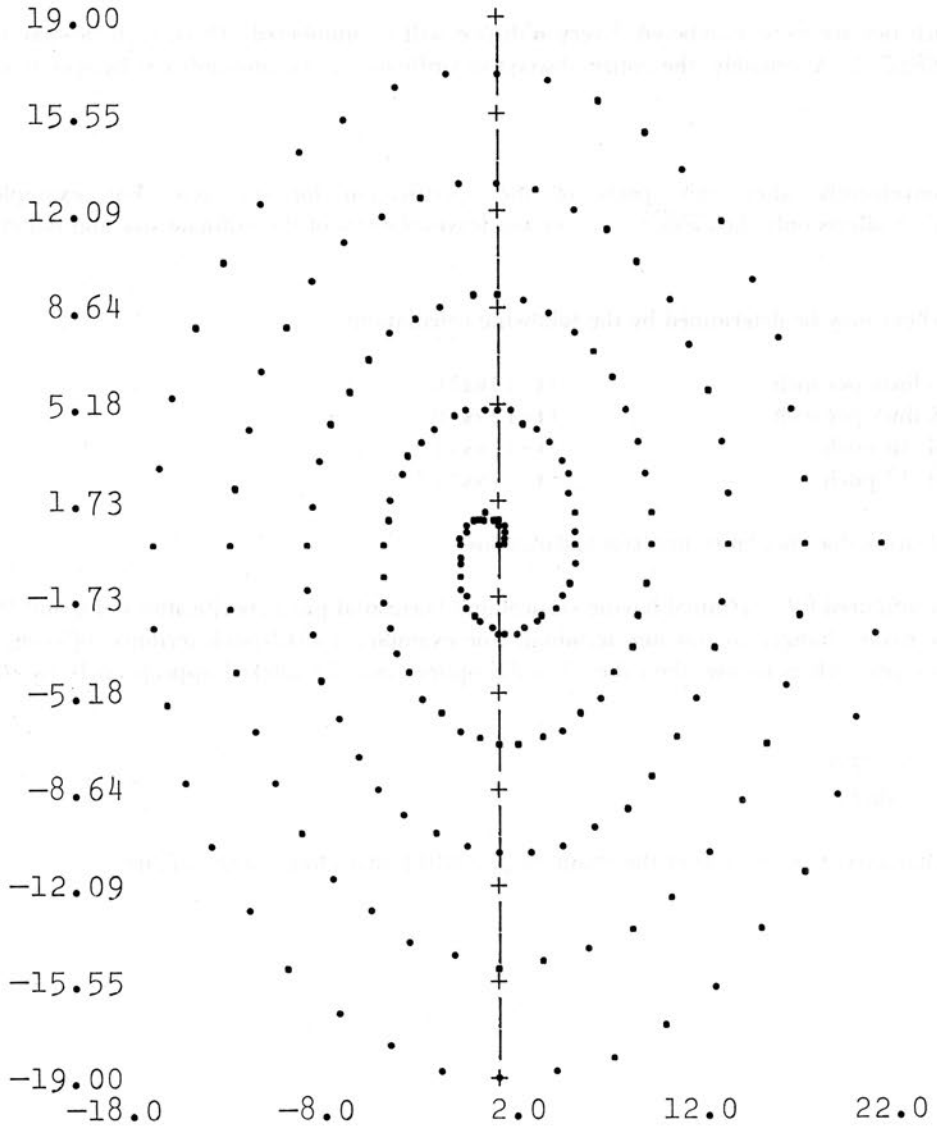
Note that the *NUMBERED* feature does not enter into size calculations.

The default display size is configured for a terminal having vertical and horizontal pitch specifications of 6 and 10, respectively. These may be easily changed to suit any terminal. For example, if a 12-pitch terminal offering a resolution of 8 vertical lines per inch is in use, then the *SPACED* options may be altered appropriately by the commands:

```
SET ORDINATE SPACED 8
SET ABSCISSA SPACED 12
```

On a terminal with these characteristics, the size of the resultant plot will remain four inches square.

```
FINEPLOT
ABSCISSACOL 1
AXES FINE, FLOATING
ORDINATE LOW LIMIT ¯19
ORDINATE HIGH LIMIT 19
SET ORDINATE TOTAL 12 SPACED 3 NUMBERED 1
SET ABSCISSA TOTAL 10 SPACED 5 NUMBERED 2
THETA←(0,ι200)×○÷20
PLOT ⍉(2 201 ρ0.1×0,ι200)× 2 1 ∘.○THETA
```



Scale Formats and Annotation

The format of the printed numbers marking the scales on the graphs may be changed if desired. The default formats are:

```
ORDINATE FORMAT 'F10.2'
ABSCISSA FORMAT 'F10.1'
```

For the ordinate, this provides space for ten character positions: seven for the integer part (including negative sign if warranted), a decimal point, and two decimal fraction digits. For the abscissa, space is again provided for ten characters: eight for the integer part, a decimal point, and one decimal fraction digit.

Any of the format phrases of □*FMT* may be used for forming numbers: *F*, *I*, *E*, or *G*. □*FMT* decorations and qualifiers (*C*, *Z*, *M*, and so on) are permitted as well. See the manual entitled "SHARP APL Report Formatting" (available from your SHARP APL representative) for more information on formatting using □*FMT*.

A left margin, if required, can be easily produced by using the *X* format phrase in the ordinate format to skip blanks. For instance, if a margin of fifteen blanks is required followed by a zero-filled integer field of width three characters, the specification `ORDINATE FORMAT 'X15,ZI3'` may be used to achieve the desired results.

If desired, a title may be conveniently centered above the plot. In addition, the left and bottom borders of the graph may be annotated. The default state for these options is:

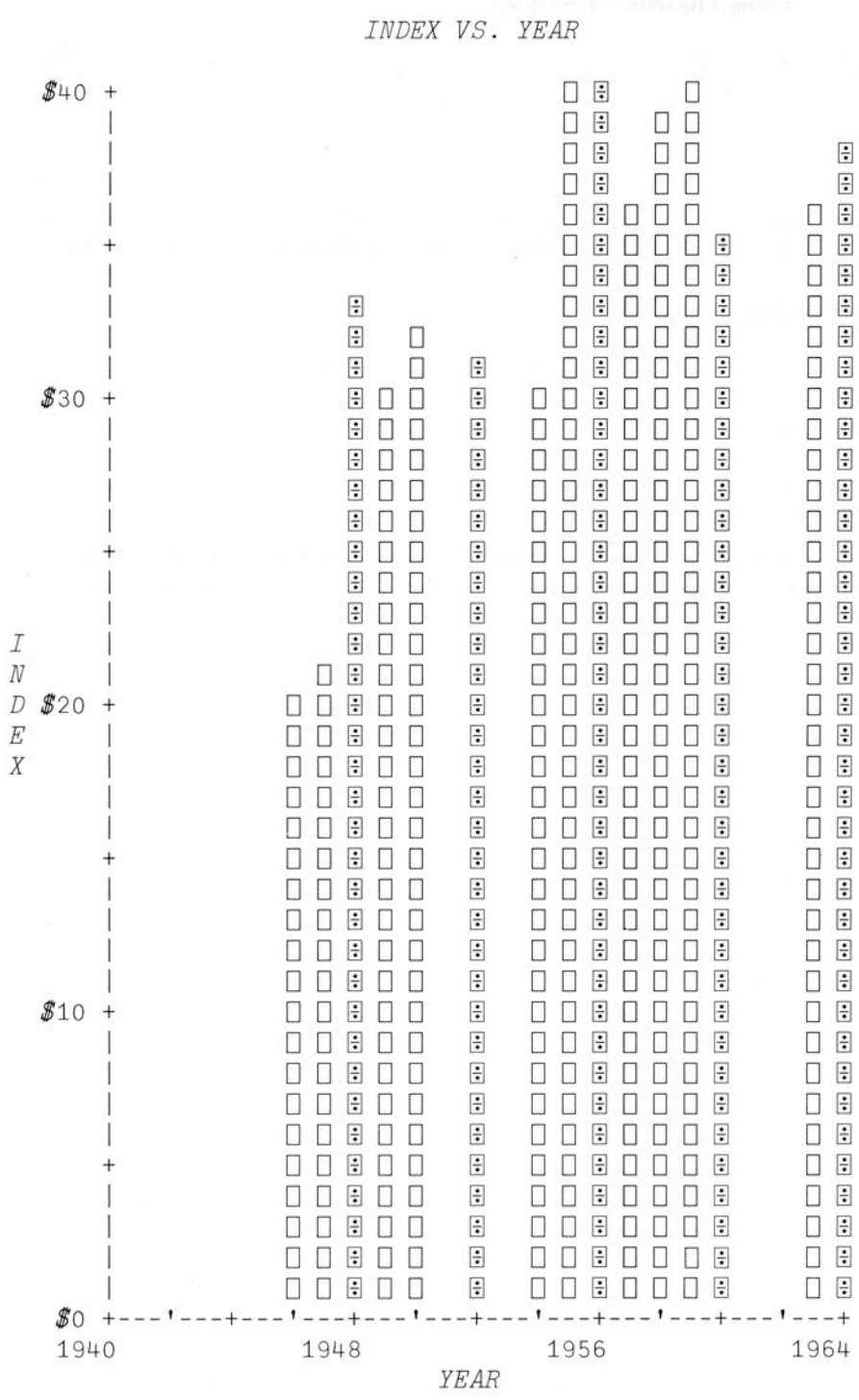
```
TITLE TEXT BLANK
ORDINATE TEXT BLANK
ABSCISSA TEXT BLANK
```

To annotate an axis, simply replace the word *BLANK* in the default state by a character vector which holds the desired annotation. For example, `ORDINATE TEXT 'CURRENT IN MILLIAMPERES'` would place that text vertically to the left of the plot. Annotation will be centered if too short, or truncated if too long (maximum 60 characters for a title, 40 for an axis).

The following example illustrates the use of these options. The data below is stored as a 15 by 3 matrix, *X*. The first column is designated as the abscissa, while the third column is the symbol column.

year	index	symbol
1946	20	1
1947	21	1
1948	33	2
1949	30	1
1950	32	1
1952	31	2
1954	30	1
1955	40	1
1956	40	2
1957	36	1
1958	39	1
1959	40	1
1960	35	2
1963	36	1
1964	38	2

```
HISTOGRAM
ABSCISSACOL 1
SYMBOLCOL 3
ORDINATE LOW LIMIT 0
ORDINATE HIGH LIMIT 40
ABSCISSA LOW LIMIT 1940
ABSCISSA HIGH LIMIT 1964
SET ORDINATE TOTAL 9 SPACED 5 NUMBERED 2
SET ABSCISSA TOTAL 7 SPACED 8 NUMBERED 2
ORDINATE FORMAT 'P□$□I4'
ABSCISSA FORMAT 'I4'
TITLE TEXT 'INDEX VS. YEAR'
ORDINATE TEXT 'INDEX'
ABSCISSA TEXT 'YEAR'
PLOTCHARS '□:'
PLOT X
```


INDEX VS. YEAR
$40
$30
$20
$10
$0
INDEX
1940
1948
1956
1964
YEAR

Using Logarithmic Scaling

The default state includes the settings:

```
ORDINATE SCALE LINEAR
ABSCISSA SCALE LINEAR
```

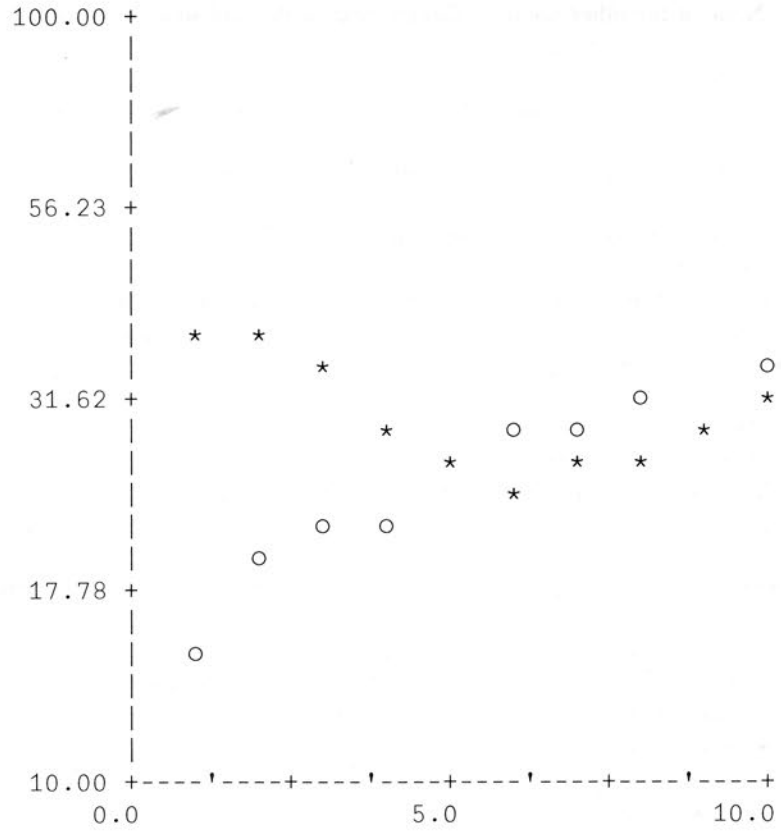
Either or both scales may be made logarithmic by replacing the word *LINEAR* in the default state by *LOGARITHMIC*. Scales designated as *LOGARITHMIC* may not have any automatic limits associated with them.

DATA in the next example is as shown on page 3.

```
      ORDINATE LOW LIMIT 10
      ABSCISSA LOW LIMIT 0
      ORDINATE SCALE LOGARITHMIC
      PLOT DATA
AUTOMATIC LIMITS NOT PERMITTED WITH LOGARITHMIC SCALING
```

This error report occurred as a result of not specifying a high limit for the ordinate scale, which was made logarithmic above. To remedy the situation, designate an upper limit and re-execute the *PLOT* function, as shown on the following page.

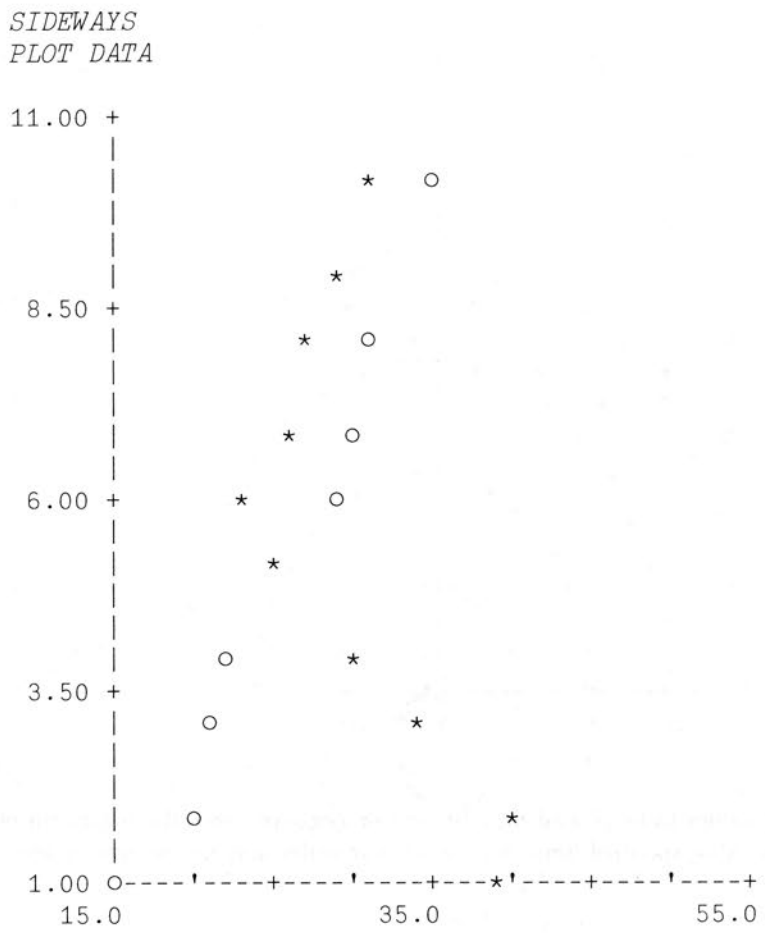
ORDINATE HIGH LIMIT 100
PLOT DATA



With logarithmic scaling, none of the values to be plotted may be zero or negative, since the logarithm of such quantities is mathematically undefined. Also, specified limits for logarithmic scales may not be zero or less.

Interchanging the Axes

It is possible to interchange the axes with the designation *SIDEWAYS*. The default setting for this option is *UPRIGHT*. When using the *SIDEWAYS* feature, the column selected as the abscissa becomes the ordinate, and all the other columns become the abscissa. None of the other options (format, text, scale, and so on) are affected by this specification.



Omitting or Doubling One or Both Axes

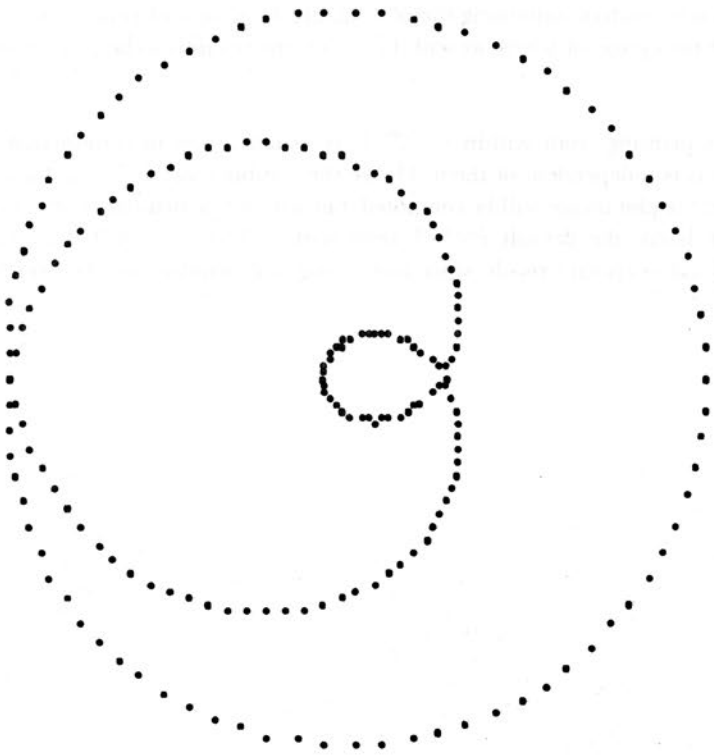
Either or both axes on the graph may be omitted entirely if desired. Alternately, an axis may be printed twice, on opposite ends of the plot. The user may control these options by using the specifications

ORDINATE		*SINGLE*
or	*AXIS*	*DOUBLE* or
ABSCISSA		*OMITTED*

The default is *ORDINATE AXIS SINGLE* and *ABSCISSA AXIS SINGLE*. Omitting an axis does not affect scale annotations. However, axes that are deleted will also be unnumbered.

If a double axis is specified, it will be placed parallel to the first and on the opposite end of the graph (on the right for the ordinate, and on the top for the abscissa). Although the second axis is unnumbered and contains no scale annotation, it is marked with plus signs at appropriate intervals corresponding to those on the first axis. Thus the double axis option is very useful for long or wide plots, and facilitates their reading greatly. Note that double axes are not permitted with the specification *AXES FLOATING*.

```
FINEPLOT
ABSCISSACOL 1
ORDINATE AXIS OMITTED
ABSCISSA AXIS OMITTED
THETA←(0,ι400)×○÷20
PLOT ⍉(2 401 ρ4×2○THETA×0.1)× 2 1 ∘.○THETA×0.5
```



Output Options

Normally, the result of executing *PLOT* is printed directly on the terminal printer from within the function, and no explicit result is returned. This is the effect of the default conditions *PRINT* (versus its alternative *NOPRINT*), and *NORESULT* (whose alternatives are *VECTOR*, *PREEDIT*, and *MATRIX*). With any of *VECTOR*, *PREEDIT*, or *MATRIX*, an explicit result is returned. The syntax of the use of plot with any of these would be

result ← *PLOT* **data**

where **result** contains the plot image. The format of the image is determined by the option chosen.

The option *VECTOR* returns a character vector, with carrier returns embedded appropriately to separate lines. One use of the *VECTOR* option is for overtyping. Suppose *FINEPLOT* is required for your application, and you wish to superimpose APL-font symbols to mark the symbols generated by different columns of the argument. To do this, simply store the *FINEPLOT* result, reset to *NORMAL*, and in the *NORMAL* result replace all graphics which are not plot characters or carrier returns by the blank character. Then overtype the two results by rolling the platen back to the same starting position.

Another use of *VECTOR* is for preparing output to be printed on the highspeed printer at the SHARP APL Computer Centre using *FILEPRINT* or *HSPRINT*. See the "SHARP APL File Subsystem Manual" (available from your SHARP APL representative) for details on the operation of the file-printing facilities.

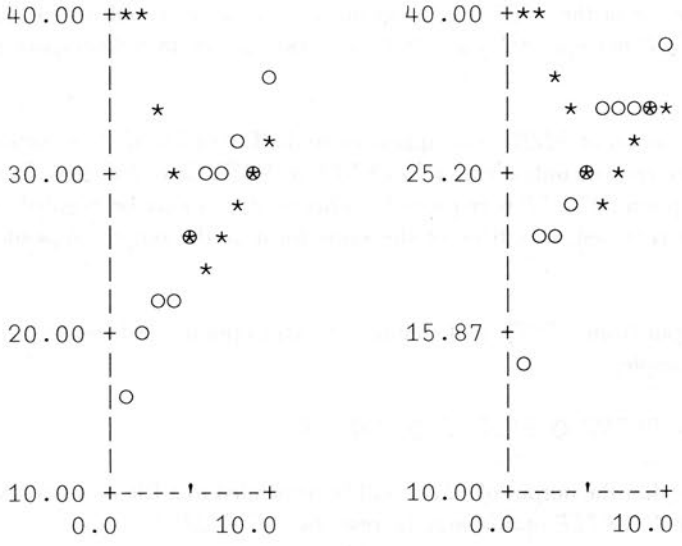
The *PREEDIT* output option produces a character vector much like *VECTOR*, except that the sequence ¨*S* is used instead of the carrier return character. This form of output is intended as input to the SHARP APL Text Editor. See the manual of the same name for more information on text editing.

The option *MATRIX* yields a character matrix containing the plot image. This form of result is useful when several plots are to be aligned side-by-side on a page, or when, as with *VECTOR*, the result is to be printed on the highspeed printer.

The *NOPRINT* option suppresses printing from within *PLOT*. It is usually used in conjunction with *VECTOR*, *PREEDIT*, or *MATRIX*, although it is independent of them. Hence the combination *NOPRINT* and *NORESULT* is permitted, but has no practical use: the plot image will be computed, but will not be printed or returned as an explicit result from *PLOT*. On the other hand, the default *PRINT* used with *VECTOR*, *PREEDIT*, or *MATRIX* has practical use for previewing the final (explicit) result, since computing and printing will be overlapped.

Below is an example of using the *MATRIX* option to produce two similar plots for alignment on a page.

```
NOPRINT
MATRIX
MULTIPLE
ORDINATE LOW LIMIT 10
ORDINATE HIGH LIMIT 40
ABSCISSA LOW LIMIT 0
SET ORDINATE TOTAL 4 SPACED 5 NUMBERED 1
SET ABSCISSA TOTAL 2 SPACED 10 NUMBERED 1
X←PLOT DATA
ORDINATE SCALE LOGARITHMIC
X,PLOT DATA
```



The options *MULTIPLE*, *FINEPLOT*, and *FINEAPL* may place certain "invisible" characters in a *MATRIX* result. While it is possible to change or insert annotation into the body of such a result, care should be taken to make sure the text is inserted in the correct locations.

Using Files for Input and Output

If desired, the SHARP APL File Subsystem may be used for both input and output to the Plot Facility. (See "SHARP APL File Subsystem Instruction Manual" for complete documentation on the use and management of files.) The option *SRCFILE* **n** controls the source of input to *PLOT*. **n** is a two-element vector designating the file number and component holding the data to be plotted. If input is to come from files, the plot function is niladic (has no arguments). Its syntax in this case would be:

```
PLOT
or
result ← PLOT
```

the latter case applying when an output option (*VECTOR*, *PREEDIT*, or *MATRIX*) has been specified. The default condition can be restored by *SRCFILE* 0.

"Appendix C" contains a discussion on the use of the *SRCFILE* program to avoid space problems in application package workspaces. Note that *SRCFILE* will not operate in a)*SEAL*'d workspace, or in a workspace in which *PLOT* is suspended.

The specification *OUTFILE* **n** permits the output of *PLOT* to be appended to the file tied to **n**. The output will be appended as a vector with embedded carrier returns unless either *PREEDIT* or *MATRIX* is specified. Further, no explicit result will be returned unless the option *RESULT* is requested. (This condition may be negated by typing *NORESULT*.) If an explicit result is to be returned, it will be of the same form as the output appended to the designated file.

When using an outfile, the first line of output from *STATE* will contain an extra option word indicating whether an explicit result is to be returned. For example,

```
APL ◇ PRINT ◇ RESULT ◇ MATRIX
```

The options *RESULT* and *MATRIX* indicate that the output of *PLOT* will be appended to a file as a matrix, as well as being returned as an explicit result. The *OUTFILE* option may be reset by *OUTFILE* 0.

Support for Various Types of Terminals

The Plot Facility supports most APL-compatible terminals, including ASCII varieties. *FINEPLOT* and *FINEAPL*, however, require a terminal equipped with an IBM Selectric printer, so that the special plotting typesphere required for those options may be used.

When using either of the high-resolution plotting options, the function *PLOT* automatically performs any necessary character translations before data is output to the terminal or returned as an explicit result. However, because of the different transmission codes available with Selectric printers, it is good practice to place the plotting typesphere on the terminal printer just prior to executing *PLOT*, and to use the APL sphere suited to that terminal at other times.

If you are using an ASCII terminal which does not have the full APL character set, the option *ASCII* (versus its default APL) should be employed. The *ASCII* option will replace certain characters in the plot image that are not available on terminals with a subset of the APL character set by other, more standard characters available on all terminals.

In addition to the plotting facilities offered by 3 *PLOT*, several other graphics workspaces are available for use with certain ASCII terminals that have a special plot mode of operation. Workspace 3 *LPLOT* supports plot facilities similar to those available in 3 *PLOT*, but designed for graphics-oriented devices. The package permits the use of "daisy-wheel" printers to produce complicated line or point plots. Dashed lines and stroke characters may also be incorporated into the plot using the software provided.

Workspace 3 *GRAPHICS* supports a wide variety of terminals with varying graphic capabilities. Simple graphic primitives permit scaling, translating, rotating, clipping, and hatching of the user's data. The primitives represent graphic objects, that is, sequences of points or lines, in a manner analagous to the way in which APL represents scalar values. In particular, objects may be catenated to form graphic vectors which may be compressed, subscripted, or manipulated in a variety of other ways. Using these primitives, the user can easily construct a specialized plotting routine to produce a desired graph. In addition, most of the programs are device-independent (with the necessary exception of the outputting routines), so that support for new terminals can be incorporated with little difficulty.

More information on the graphics facilities available may be obtained through your local SHARP APL representative.

Appendix A

Summary of State-setting Functions

This appendix gives a summary of each state option in the form of its syntax and a brief description of its effect. Options are listed in the order they appear in the output of *STATE*. On each syntax line, the specification shown first is the default setting of that option. The following notation is used:

character vector	A character vector containing title or scale annotation.
column	A non-negative integer value designating a column in the argument matrix to *PLOT*.
component number	A non-negative integer value designating the position of a component in the source file to *PLOT*.
file number	A non-negative integer value designating the file tie number of the source or output files to *PLOT*.
format phrase	A character vector containing a valid format phrase to be used in forming the numbers for the axis associated with it.
i	A non-negative integer value designating a size or decoration pattern factor for an axis.
plot characters	A character vector containing a sequence of symbols to be used as plot characters.
scale limit	A numeric value designating an upper or lower scale limit on a plot.
[phrase1 | phrase2]	Indicates that **exactly one** phrase from those listed is required. For example, [**m** | **n**] indicates that either **m** or **n**, but not both, is permitted.
[phrase1] [phrase2]	Indicates that **at least one** phrase from those listed is required; however, more than one may be present if desired. For instance, [**m**] [**n**] indicates that either or both **m** and **n** are valid.
	Indicates character-valued information between the quotation marks.

[*APL*|*ASCII*]

Indicates the type of terminal. Use the *ASCII* option if the terminal you are using does not support the full APL character set.

[*PRINT*|*NOPRINT*]

Controls the printing of output on the terminal printer from within *PLOT*.

[*NORESULT*|*RESULT*]

Determines if an explicit result will be returned by the *PLOT* function. If a result is to be returned, it will be a vector with embedded carrier returns unless either *PREEDIT* or *MATRIX* is specified as well.

[*VECTOR*|*PREEDIT*|*MATRIX*]

Determines the format of the explicit result or output file component.

VECTOR - Result is a character vector with carrier returns embedded appropriately.
PREEDIT - Similar to *VECTOR*, except that the sequence ¨*S* is used instead of the carrier return character.
MATRIX - Result is a character matrix containing the plot image.

[*NORMAL*|*HISTOGRAM*|*FINEPLOT*|*FINEAPL*]

Controls the style of the output image.

NORMAL - Produces a standard plot of the data. Each column of the argument is plotted using a different symbol.
HISTOGRAM - Produces a histogram of the data. Once plotted, each data point is reprinted in the same position on each subsequent line on the graph.
FINEPLOT - A high-resolution plotting option requiring a special plotting typesphere. Three symbol-sets are available with *FINEPLOT*.
FINEAPL - Similar to *FINEPLOT*, but offers three more distinct symbol-sets by using APL characters on the plot.

[*SINGLE*|*MULTIPLE*]

Controls whether or not concurrent points will be overstruck. With *SINGLE*, where two or more points coincide, the symbol associated with the latter column is used. If *MULTIPLE* is in effect, the symbols will be overstruck. This option does not apply to either *FINEPLOT* or *FINEAPL*.

[UPRIGHT|SIDEWAYS]

Determines the coordinate to be used as the independent variable. With *SIDEWAYS*, the axes are interchanged; the column selected as the abscissa becomes the ordinate, and all other columns become the abscissa. Formats, scale limits, and so on are not changed.

SRCFILE [0|**file number, component number**]

Determines the source of input to *PLOT*. **File number** and **component number** indicate the file and location within that file of the data to be plotted. Note that the *PLOT* function is niladic if data is to come from files.

OUTFILE [0|**file number**]

Determines if the output of *PLOT* will be appended to files. The appended output will be a vector unless either *PREEDIT* or *MATRIX* is specified.

ABSCISSACOL [0|**column**]

Selects the designated column of the plot matrix to be used as the abscissa values for the dependent variables.

SYMBOLCOL [0|**column**]

Selects the designated column of the plot matrix as that indicating the symbol to be used for the corresponding row of the matrix.

AXES [*BROAD*|*FINE*]

Determines the width of the characters used to form the ordinate and abscissa borders when using *FINEPLOT* or *FINEAPL*.

AXES [*FIXED*|*FLOATING*]

Determines if the axes on the graph will be drawn at the left and bottom borders (*AXES FIXED*) or wherever zero is on the scale (*AXES FLOATING*). If zero is not marked, no line is drawn.

ALL LIMITS AUTOMATIC
[*ORDINATE*|*ABSCISSA*] [*LOW*|*HIGH*] *LIMIT* [*AUTOMATIC*|**scale limit**]

Specifies the limits of the range of data to be plotted. Data outside specified limits is ignored. Automatic limits are chosen to encompass all data points to be plotted as best as possible.

SET ORDINATE [*TOTAL* [5|**i**]] [*SPACED* [6|**i**]] [*NUMBERED* [1|**i**]]

Determines display size and decoration pattern for the ordinate scale.

SET ABSCISSA [*TOTAL* [6|**i**]] [*SPACED* [10|**i**]] [*NUMBERED* [2|**i**]]

Determines display size and decoration pattern for the abscissa scale.

[*ORDINATE*|*ABSCISSA*] *AXIS* [*SINGLE*|*DOUBLE*|*OMITTED*]

Specifies one (*SINGLE*), two (*DOUBLE*), or no (*OMITTED*) axes to be printed. If a second axis is desired, it will be placed on the opposite side of the plot from the first one. Note that double axes are not permitted with *AXES FLOATING*.

[*ORDINATE*|*ABSCISSA*] *SCALE* [*LINEAR*|*LOGARITHMIC*]

Controls the scaling of axes as linear or logarithmic. Automatic limits are not permitted with logarithmic scaling. Also, specified limits or data points to be plotted may not be zero or less for logarithmic axes.

ORDINATE FORMAT ['*F*10.2'|'**format phrase**']

Specifies the format phrase to be used in numbering the ordinate axis.

ABSCISSA FORMAT ['*F*10.1'|'**format phrase**']

Specifies the format phrase to be used in numbering the abscissa axis.

[*TITLE*|*ORDINATE*|*ABSCISSA*] *TEXT* [*BLANK*|'**character vector**']

Controls title and scale annotation on the plot. Text is centered if too short, or truncated if too long.

PLOTCHARS ['○*×+∘▽△□⊤⊥ω⊂⊃∩∪' | '**plot characters**']

Sets the symbols to be used as plot characters for sucessive columns in the data matrix. If there are more columns to be plotted than plot characters, then the symbols will be repeated as necessary. This option does not apply to *FINEPLOT* or *FINEAPL*.

Appendix B

Summary of Error Reports

This appendix describes the possible error reports a user might encounter while using the Plot Facility. Along with each report is listed the names of the functions in which it may occur, its cause, and a suggested remedy to the problem.

AUTOMATIC LIMITS NOT PERMITTED WITH LOGARITHMIC SCALING

Function: *PLOT*
Cause: A scale limit that has been specified as logarithmic has one or more automatic limits associated with it.
Remedy: Indicate specific limits for those that were automatic on the offending scale, and re-execute the *PLOT* function.

DOUBLE AXES NOT PERMITTED WITH AXES FLOATING

Function: *PLOT*
Cause: The option *AXES FLOATING* has been specified concurrently with one or more double axes.
Remedy: Execute *AXES FIXED*, or remove the *DOUBLE* specification from the appropriate axes.

FORMAT PHRASE TOO LONG

Function: *FORMAT*
Cause: The format phrase specified is longer than the maximum of fifteen characters.
Remedy: Restructure the format phrase so that its length is fifteen characters or less.

NONPOSITIVE VALUES UNACCEPTABLE FOR LOG SCALE

Function: *PLOT*
Cause: One or more specified limits, or data point coordinates corresponding to logarithmic scales, are less than or equal to zero.
Remedy: Correct the appropriate limit specifications or data points, and re-execute the *PLOT* function.

ONLY FIRST **n** *CHARACTERS USED*

Function: *PLOTCHARS* or *TEXT*
Cause: The plot characters or text specified is longer than the number of permissible characters, **n**.
Remedy: None. However, if this message occurs as a result of setting title or scale annotation using the *TEXT* function, it may be desirable to reword the annotation so that it fits in **n** characters.

OUTFILE **file number** *NOT TIED*

Function: *PLOT*
Cause: The file to which the output of *PLOT* is to be appended is not tied to **file number**.
Remedy: Tie the appropriate file to **file number**, or respecify the output file using the *OUTFILE* function.

PLOT ARGUMENT UNACCEPTABLE

Function: *PLOT*
Cause: The argument to *PLOT* is not a non-empty numeric vector or matrix, or the *ABSCISSACOL* or *SYMBOLCOL* options, if set nonzero, do not point to valid columns in the data matrix.
Remedy: Alter the abscissa and symbol column designations if necessary, and then re-execute the *PLOT* function with a properly-structured argument.

PLOT COMPONENT UNACCEPTABLE

Function: *PLOT*
Cause: The file component containing the input to *PLOT* does not exist, or does not constitute a valid *PLOT* argument (see previous error report).
Remedy: Alter the *ABSCISSACOL*, *SYMBOLCOL*, and *SRCFILE* designations if necessary, and then re-execute the *PLOT* function.

PLOT STATE UNACCEPTABLE

Function: *PLOT*
Cause: The current settings of one or more of the plotting options is invalid. This can occur if the user has manually altered the state variables, or if an incorrect state command was used to change an option.
Remedy: Use the *STATE* function to display the current settings of all options. Then change those that are incorrect or differ from the desired values, and re-execute the *PLOT* function.

SRCFILE ARGUMENT UNACCEPTABLE

Function: *SRCFILE*
Cause: The argument to *SRCFILE* is not 0 or a two-element numeric vector.
Remedy: Execute the *SRCFILE* function again with a proper argument.

SRCFILE INOPERATIVE IN A SEALED WORKSPACE

Function: *SRCFILE*
Cause: An attempt has been made to use the *SRCFILE* function to change the source of input to *PLOT* while in a)*SEAL*'d workspace.
Remedy: If an unsealed maintenance version of the workspace exists,)*LOAD* it and execute the *SRCFILE* function there before performing the)*SEAL*. If no maintenance version is available, the plot should be carried out in another workspace, for example, 3 *PLOT*. If desired, the *OUTFILE* option may be used to afford a convenient means of transferring the plotted output back to the original workspace.

SRCFILE INOPERATIVE WITH PLOT FUNCTION SUSPENDED

Function: *SRCFILE*
Cause: An attempt has been made to use the *SRCFILE* function to change the source of input to *PLOT* while *PLOT* was suspended.
Remedy: Remove *PLOT* from the state indicator stack by executing an appropriate number of branch arrows, →, or by typing)*RESET*.

SRCFILE **file number** *NOT TIED*

Function: *PLOT*
Cause: The file specified as the source of input to *PLOT* is not tied to **file number**.
Remedy: Tie the appropriate file to **file number**, or respecify the input file using the *SRCFILE* function.

SYMBOL TABLE FULL ERROR

Function: An APL error.
Cause: An attempt has been made to add more symbols to the symbol table in the active workspace than there are slots available.
Remedy: The normal remedy to this problem is:

```
)SAVE APPLICATIONWS
)CLEAR
)SYMBOLS n
)COPY APPLICATIONWS
)WSID APPLICATIONWS
)SAVE
```

WHERE **n** represents a new, suitably large size for the symbol table. If the error occurred while trying to copy objects into the workspace, the appropriate *)COPY* command may be re-executed before the *)WSID*.

SYNTAX ERROR

Function: An APL error.
Cause: The name of a function has been mistyped; an argument was supplied to *PLOT* when the source of input was files, or no argument was supplied with *SRCFILE* 0 in effect.
Remedy: Re-enter the statement correctly.

VALUE ERROR

Function: An APL error.
Cause: The name of a plotting function has been mistyped.
Remedy: Re-enter the line correctly.

WS FULL

Function: An APL error.
Cause: All available space in the active workspace has been used.
Remedy: If the state-setting functions can be erased from the workspace, type *)ERASE ANCILLARY*. In the event that they are needed later, these functions can always be copied in again via *)COPY* 3 *PLOT ANCILLARY*. If the error occurred while *PLOT* was in progress, execution may be resumed by typing *→⎕LC*. If the problem persists even after all unnecessary functions have been erased, contact your local SHARP APL representative or the APL operator for further assistance.

WS NOT FOUND

Function: An APL error.
Cause: You have made an error in typing the name or library number of the plotting workspace.
Remedy: Re-enter the *)LOAD* statement correctly.

Appendix C

Application Package Considerations

When using *PLOT* within an application workspace, there are a number of factors which can contribute to possible *WS FULL* conditions. For example, the argument to *PLOT* is often quite large, *PLOT* uses a considerable amount of intermediate storage, and there may be other programs within the workspace when *PLOT* is executed.

Once the options have been set up to obtain the desired patterns, all objects other than *PLOT*, *CQ*, and *CHARS* may be erased. This can be done conveniently by erasing the group *ANCILLARY*, or by saving the active workspace in the user's private library, loading the application workspace, and copying the group *ESSENTIAL*. Should this result in a *SYMBOL TABLE FULL ERROR*, consult "Appendix B" to this manual for information on how to correct the problem.

If very large arguments are to be used, it is suggested that the data be stored as a file component and that the *SRCFILE* and *OUTFILE* options be used to manipulate it.

Because the *PLOT* function itself occupies a fair amount of space, it is often undesirable to have it resident in the workspace at all times. For non-)*SEAL*'d packages in which storage considerations are important, the *SRCFILE* function may be used to create *PLOT* whenever the program is required. For example, *SRCFILE* `0` will make *PLOT* available with the source of input being its argument. One or more plots may then be carried out, and the function subsequently dynamically erased using □*FD*.

Any of the state-setting functions in workspace `3` *PLOT* may be embedded within the user's application programs. Most of the state-setting functions have been intentionally left unlocked, so that you may set the options directly by displaying the appropriate functions and incorporating equivalent expressions in your programs. Locked functions, including *PLOT* itself, are proprietary features of the Plot Facility and of the SHARP APL System, and hence are locked.

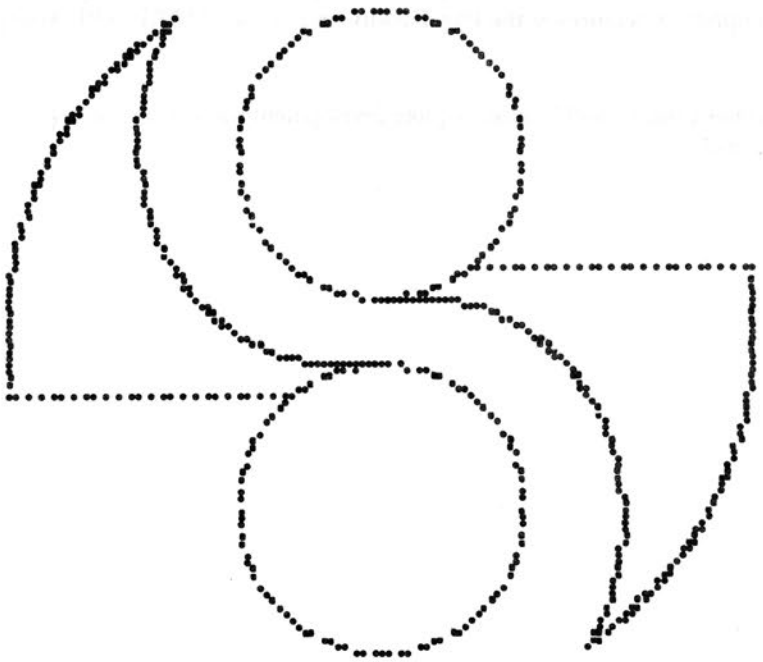
The staff of I.P. Sharp Associates Limited will be glad to quote development costs for making specialized adaptations of *PLOT* should they be required.

Appendix D

Some Examples of Use

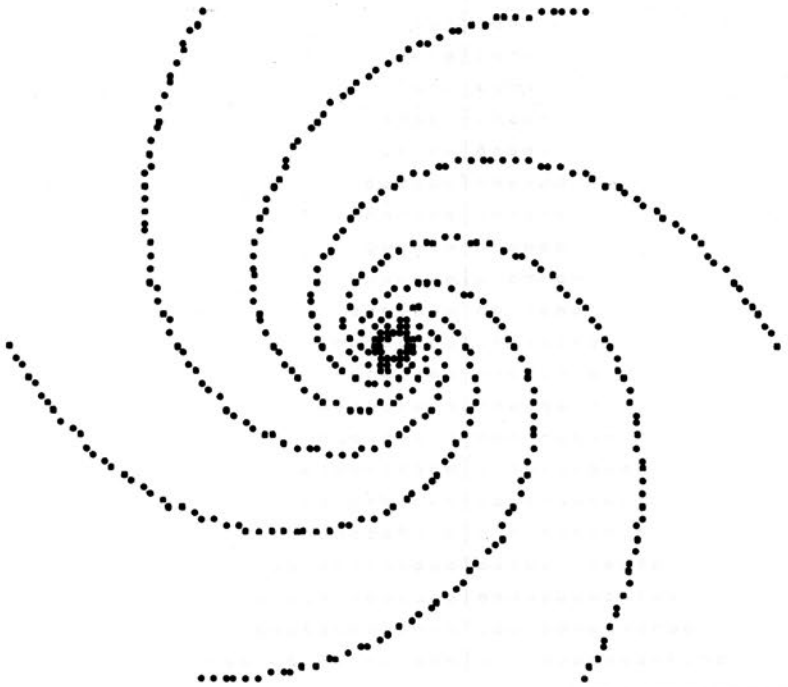
Example 1

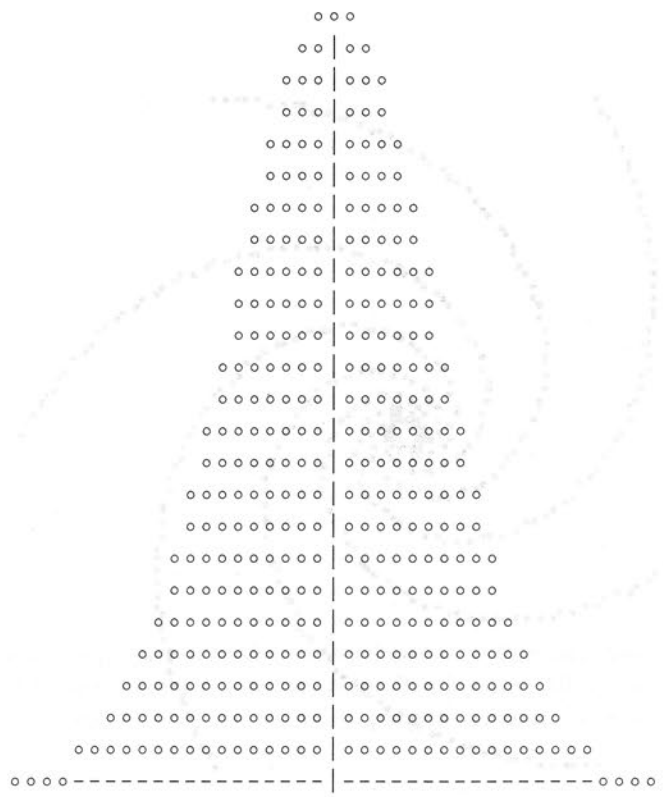
```
    ∇ Z←IPSYM;I
[1]   Z←⍉34× 2 1 ∘.○2.18+0.175×I←(⍳100)×○0.02
[2]   Z←Z,[1]-Z←Z,[1]((¯4+18×2○I),[1.5] 17+20×1○I←2.5+0.38×I),
      [1]((13×2○I),[1.5] ¯16+13×1○I),[1]-(8+⍳26),[1.5] 6
    ∇

      FINEPLOT
      ABSCISSACOL 1
      ORDINATE LOW LIMIT ¯29
      ORDINATE HIGH LIMIT 29
      ABSCISSA LOW LIMIT ¯35
      ABSCISSA HIGH LIMIT 35
      SET ORDINATE SPACED 5
      ORDINATE AXIS OMITTED
      ABSCISSA AXIS OMITTED
      PLOT IPSYM
```



Example 2

```
    ∇ Z←I BUGPATH J;K;P
[1]   Z←I←⍉ 2 1 ∘.○○2×(⍳I)÷I
[2]  L0:Z←Z,[1] I←I-(J÷(⍴I)⍴K←(+/P*2)*0.5)×P←I-1⊖I
[3]   →L0×(⌈/K)>J×1.1
    ∇

      FINEPLOT
      ABSCISSACOL 1
      ORDINATE AXIS OMITTED
      ABSCISSA AXIS OMITTED
      PLOT 6 BUGPATH 0.03
```



Example 3

```
    ∇ Z←BELLCURVE
[1]   Z←¯51+⍳101 ◇ Z←Z,[1.5]*¯0.5×(Z×0.065)*2
    ∇

      HISTOGRAM
      ABSCISSACOL 1
      AXES FLOATING
      ABSCISSA LOW LIMIT ¯50
      ABSCISSA HIGH LIMIT 50
      SET ORDINATE NUMBERED 0
      SET ABSCISSA NUMBERED 0
      PLOTCHARS '∘'
      PLOT BELLCURVE
```